

REMARKS

Claims 1-7 and 17-20 were examined. Claims 1 and 6 are amended. Claims 1-7 and 17-20 remain in the application.

A. 35 U.S.C. §102(b): Rejection of Claims 1-4 & 6-7

The Patent Office rejects claims 1-4 and 6-7 under 35 U.S.C. §102(b) as anticipated by or under 35 U.S.C. §103(a) as obvious over "Role of N₂ Addition on CF₄/O₂ Remote Plasma Chemical Dry Etching of Polycrystalline Silicon," Matsuo et al. (Matsuo).

Independent claim 1 describes an apparatus including a first reaction chamber, a gas source coupled to the first reaction chamber to supply a nitrogen gas to the first reaction chamber and an excitation energy source coupled to the first reaction chamber to generate a nitrogen plasma comprising nitrogen ions and radicals from the nitrogen gas. The apparatus also includes a second reaction chamber adapted to house a substrate for film formation at a site in the second reaction chamber. The first reaction chamber is coupled to the second reaction chamber and separated from the substrate site by a distance equivalent to the lifetime of the nitrogen ions at a plasma generation rate such that the radicals react with the substrate in a film conversion step.

Matsuo describes experimental etching procedures, specifically, chemical dry etching of silicon. Matsuo describes generating a microwave plasma in a plasma applicator coupled to a processing chamber for an etch process. The plasma is separated from the processing chamber by tubing of various lengths (0 to 125 centimeters). Matsuo describes etching silicon in a CF₄ plasma with oxygen (O₂) and/or nitrogen (N₂) addition.

Independent claim 1 is not anticipated by and is prima facie not obvious over Matsuo, because Matsuo does not describe:

(1) a second reaction chamber adapted to house a substrate for film formation;

Matsuo describes only etching of silicon. **It has never been established that Matsuo describes a film formation step.**

The Patent Office references page 1805 describing a "reaction layer." As a preliminary matter, the cited text does not describe nitrogen (either plasma or ions) specifically being incorporated in a reaction layer.

Strong surface chemical changes are observed upon N₂ addition, although little nitrogen is incorporated in the reaction layer. The nitrogen is reactive only as a reactive intermediate. Depending on the O₂/CF₄ ratio, i.e., the predominance of F or O, either thinning or thickness growth of the modified surface layer can be seen.

Matsuo, page 1813.

Further, as the Patent Office is undoubtedly aware, CF₄ is a common species for plasma etching of silicon and has been extensively studied. Applicants include herewith as Appendix A, a copy of relevant pages of "Silicon Processing for the VLSI Era, Volume 1: Process Technology," by S. Wolf and R.N. Tauber (1986) ("Wolf"). Specifically, pages 547-551 titled "Etching Silicon and Silicon Dioxide in Fluorocarbon-Containing Plasmas" are provided. The authors of the cited treatise describe a CF₄ plasma etching of silicon as accomplished not by the CF₄ molecules, but by radical species created by the dissociation of CF₄ molecules; namely fluorine atoms. See id. at 548. The products of the silicon-etching reaction are SiF₄ and SiF₂. Id. The addition of oxygen (O₂) to the CF₄ feed up to 20 percent by volume tends to increase the etch rate by increasing the fluorine-concentration available for reaction with silicon. See id. at 549. Although the exact reason for this increase of etch rate is debated, there is no debate that it is still only fluorine (not oxygen and fluorine) that reacts with the silicon. See id.

Matsuo generally confirms the content of Appendix A. Matsuo additionally considers nitrogen's effect on the fluorine reaction with silicon. Matsuo does not ever say that nitrogen reacts with the silicon or is significantly present in a reaction layer for such reaction. Further, it cannot be assumed that nitrogen is present in the reaction layer because a reaction layer thickness might be increased with nitrogen addition to the CF₄ feed. Referring again to the text in Appendix A, one theory for the increase in etch rate due to the presence of oxygen is that CF₃ radicals are absorbed on the silicon surface and the oxygen reacts with the carbon atom (not the silicon), leaving three fluorine atoms available for reaction. See Wolf, page 549. Interpreting Matsuo, it is plausible that nitrogen's role is to also increase the fluorine species (e.g., F, CF₂, CF₃, etc.) available at the silicon surface (e.g., absorbed on the silicon surface) to react with silicon thus increasing a thickness of the reaction layer. It is noteworthy that, regardless of the species present, Matsuo is describing etching silicon. Certainly, it is not conceivable that the removal of silicon would result in the conversion of a film post etching. Matsuo is removing material—silicon—through a chemical process involving the reaction of fluorine with silicon. Material is being removed not added.

(2) that the first reaction chamber is separated from a substrate site by a distance equivalent to the lifetime of nitrogen ions at a plasma's generation rate such that radicals react with the

substrate in a film conversion step. This is a structural limitation of claim 1, not merely an intended use.

Matsuo describes etching, not film formation. Matsuo does not say that nitrogen is incorporated in any film formation layer, even a reaction layer formed as part of a chemical dry etching process ("even though nitrogen plays a profound role in the etching of silicon, it is not incorporated in a stable reaction layer." III.C.3 (1806)). Thus, Matsuo does not describe specifying a distance between its plasma applicator and its processing chamber so that nitrogen ions do not react with the substrate. Such a limitation also cannot be inherent in Matsuo because Matsuo clearly states that nitrogen is not significantly involved in its reaction layer (plasma or ions).

The Patent Office compares tube lengths (12 in.) noted in both references. Applicants question whether similar tube lengths in significantly different environments would produce similar results. Applicants' skepticism is supported by Matsuo's statement that nitrogen is not significantly present in the reaction layer (for etching). Applicants specifically request that the Patent Office provide some evidence or teaching that allows it to assume the separation between Matsuo's plasma applicator and a substrate site is nitrogen ion free and provides radicals available to react with a substrate.

With regard to the rejection under 35 U.S.C. §103(a), there is no motivation in Matsuo for reacting radicals with a substrate in a film conversion step or for separating a plasma from a silicon etching environment in the presence of nitrogen. With respect to film conversion, Matsuo is completely silent. Matsuo describes removing silicon, through the reaction of fluorine with silicon. There is no teaching even in the context of the possible presence of nitrogen in a reaction layer that there is a film conversion step taking place.

With regard to separating a plasma generation chamber from a reaction chamber, Matsuo indicates that, in the presence of nitrogen, zero tube length (i.e., no separation between plasma applicator and etching chamber) is best:

Section III.A.2 and Figure 4 (page 1803): Teaches that zero tube length yields the highest etch rate when nitrogen gas is added to the existing to an existing plasma discharge.

Section III.C.4 (page 1809): Describes an etch reaction layer thickness for various tube lengths. Concludes:

"For discharges devoid of oxygen, the behaviors of the reaction layers are similarly, both with and without admixed nitrogen, constant with increasing quartz tube length."

When both N₂ and O₂ are admixed into a CF₄ discharge, "the thickness stayed constant with increasing quartz tube length."

Section IV.B (page 1812): Describes the etch rate and atomic fluorine concentration for various tube lengths, Matsuo shows that, in the presence of nitrogen, as the tube length is increased the etch rate drops off.

According to the structural limitations of claim 1, where the first reaction chamber and a substrate (e.g., wafer) site are separated by a distance equivalent to the lifetime of nitrogen ions at a plasma generation rate, only radicals from the nitrogen plasma reach a wafer for film conversion. Any ions generated in the plasma are neutralized due to the length of, for example, a tube or conduit. See Application, page 4, lines 16-18. Charged particles of a plasma are not available to sputter a wafer and thus, by way of structural limitations of claim 1, a relatively damage free dielectric layer may be produced. See Application, page 15, lines 10-17. Matsuo does not teach or suggest such a result. Matsuo is concerned with removing silicon with fluorine species. Matsuo is not concerned with nitrogen ions or radicals at the reaction site.

For the above stated reasons, claim 1 is not anticipated by and is not obvious over Matsuo. Claims 2-4 depend from claim 1 and therefore include all the limitations of that claim. For at least the reasons stated with respect to claim 1, claims 2-4 are not anticipated by and is not obvious over Matsuo.

Independent claim 6 describes an apparatus including a first reaction chamber; means for supplying a nitrogen gas to the first reaction chamber; and means for generating a plasma from the nitrogen gas. The apparatus also includes a second chamber having means for housing a substrate for film formation processing and means for providing the plasma to the reaction chamber substantially free of nitrogen ions such that radicals from the plasma react with a substrate in a process conversion step.

Claim 6 is not anticipated by and it not obvious over Matsuo because Matsuo does not describe, among other things, means for providing a plasma (of nitrogen) to a reaction chamber substantially free of nitrogen ions such that radicals react with a substrate housed for film formation in a process conversion step. Such means is a structural limitation of the apparatus in that, in one sense, it establishes the relationship between the generated plasma and a second reaction chamber.

Matsuo does not describe introducing a nitrogen plasma to a chamber substantially free of ions. Matsuo also does not describe providing nitrogen radicals that may react with a substrate in a process conversion step.

Applicants also believe that claim 6 is not obvious over Matsuo, because Matsuo provides no motivation for including means for providing a plasma to a second reaction chamber in such a way that radicals react with a substrate in a process conversion step. As noted above with respect to claim 1, to the extent that a nitrogen plasma is generated in Matsuo, Matsuo does not say that nitrogen is involved in the etching process. Matsuo also sees no benefit from separating, such as by a quartz or teflon tube, a plasma generation site from an etching chamber when nitrogen is incorporated into the etchant medium.

Independent claim 6 is not anticipated by and is not obvious over Matsuo. Claim 7 depends from claim 6. For at least the reasons stated with respect to claim 6, claim 7 is not anticipated by and is not obvious over Matsuo.

B. 35 U.S.C. §102(b): Rejection Claims 17-20

The Patent Office rejects claims 17-20 under 35 U.S.C. §102(b) as anticipated by U.S. Patent No. 5,082,517 issued to Moslehi (Moslehi).

Independent claim 17 relates to a system including a first chamber; a nitrogen gas source coupled to the first chamber and an energy source coupled to the first chamber. The system also includes a second chamber configured to house a substrate for film formation processing and a system controller configured to control the introduction of a gas from the gas source into the first chamber and to control the introduction of an energy from the energy source. The system also includes a memory coupled to the controller and instructions for controlling the gas source and the energy source to convert a portion of a nitrogen gas supplied by the gas source into a plasma. The first reaction chamber is separated from the second reaction chamber by a distance equivalent to the lifetime of nitrogen ions at a plasma generation rate such that radicals react with a substrate in the second chamber in a film conversion step.

Independent claim 17 is not anticipated by Moslehi, because Moslehi does not describe a system including a first reaction chamber and a second reaction chamber that are separated by a distance equivalent to the lifetime of nitrogen ions at a plasma generation rate such that radicals react with a substrate in the second chamber in a film conversion step. Moslehi teaches preferably introducing both charged and neutral species to a process chamber. Independent claim 17 is directed at minimizing "charged" species by the structural limitation of separating a plasma

generation chamber ("first chamber") from a substrate site by distance equivalent to a lifetime of nitrogen ions. The Patent Office relies on column 4, lines 9-14 of Moslehi as teaching this language. The cited language does not teach the structural limitation regarding the relationship between a first chamber and a substrate site as required by claim 17. This language only describes a capability of a plasma density controller. Similarly, the Patent Office relies on column 11, lines 54-63 of Moslehi. The cited language describes a plasma generation tube of a certain dimension not a separation between the plasma generation tube and a processing chamber. The cited language does not describe a relationship between the plasma generation tube and a process chamber (e.g., the distance between the plasma generation tube and a process chamber).

In terms of obviousness, Moslehi does not provide any motivation for a system where a first reaction chamber and a second reaction chamber is separated by a distance equivalent to the lifetime of nitrogen ions at a plasma generation rate, because Moslehi prefers introducing both charged and neutral species to a reaction chamber.

"Consequently, there is a need for a device that adjustably controls the plasma-generating electromagnetic power that a fabrication process gas receives to produce a processed plasma consisting of activated charged and neutral species."

Col. 2, lines 37-41.

As noted above with respect to Matsuo, by separating a first reaction chamber and a second reaction chamber by a distance equivalent to the lifetime of ions at a plasma generation rate, only radicals reach a wafer for reaction. Charged particles (e.g., nitrogen ions) are not available to sputter a substrate and thus a relatively damage free dielectric layer may be produced. Moslehi does not teach or suggest such a result.

For the above stated reasons, claim 17 is not anticipated by Moslehi. Claims 18-20 depend from claim 17 and therefore contain all the limitations of that claim. For at least the reasons stated with respect to claim 17, claims 18-20 are not anticipated by Moslehi.

Applicants respectfully request that the Patent Office withdraw the rejection to claims 17-20 under 35 U.S.C. §102(b).

C. 35 U.S.C. §103(a): Rejection of Claim 5

Claim 5 is rejected under 35 U.S.C. §103(a) as obvious over Matsuo in view of U.S. Patent No. 6,130,118 issued to Yamazaki (Yamazaki). Yamazaki is cited for describing a plasma reaction apparatus for film deposition.

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Claim 5 depends from claim 1 and therefore contain all the limitations of that claim. Accordingly, claim 5 is not obvious over the cited references because the references do not disclose or provide any motivation for an apparatus including a first reaction chamber coupled to a second reaction chamber having a substrate site separated by a distance equivalent to the lifetime of nitrogen ions at a plasma generation rate.

Applicants respectfully request that the Patent Office withdraw the rejection to claim 5 under 35 U.S.C. §103(a).

CONCLUSION

In view of the foregoing, it is believed that all claims now pending patentably define the subject invention over the prior art of record and are in condition for allowance and such action is earnestly solicited at the earliest possible date.

Respectfully submitted,

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Dated: 5/8/03

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SILICON PROCESSING FOR THE VLSI ERA

**VOLUME 1:
PROCESS TECHNOLOGY**

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APPENDIX A

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involves the control of the large number of parameters that affect the process. Figure 5 illustrates some of the parameters that impact the gas-phase interactions, as well as the surface-plasma interactions. Although many macroscopic parameters can be controlled, such as the type of feed gas, power, and pressure, the precise effect of making any changes in these parameters is usually not well understood. In fact, a change in a single macroscopic parameter typically alters two or more basic *plasma* parameters, and possibly one or more of the surface parameters, such as temperature or electrical potential. This makes process development in plasma systems a challenge, and the use of factorial experimental design techniques for such tasks very useful⁹ (see Chap. 18). In the introduction to the section on *Dry-Etch System Configurations*, a discussion is presented on how gas flow, pumping speed, and pressure are interrelated, and how this interrelationship is used to control pressure.

ETCHING SILICON and SILICON DIOXIDE in FLUOROCARBON-CONTAINING PLASMAS

The etching of silicon and SiO_2 in fluorocarbon plasmas is described in this section in substantial detail. This is done because these etching processes are very important in silicon VLSI fabrication. In addition, when the mechanisms of plasma etching were being first studied, the etching of silicon and SiO_2 in plasmas containing CF_4 , mixtures of $\text{CF}_4 + \text{O}_2$, and mixtures of $\text{CF}_4 + \text{H}_2$, yielded important data about many of the fundamental mechanisms that are operative in plasma etching, as well as information about the specific materials system under investigation. The conclusions from these studies led to the development of two models for organizing chemical and physical information on plasma etching. These models are the *fluorine-to-carbon ratio model* (or *F/C model*)¹⁰, and the *etchant-unsaturate model*¹¹. Since the models are conceptually similar, although they emphasize different aspects of plasma etching, we describe only the F/C model. Details of the etchant-unsaturate model are given in Ref. 25.

We begin the discussion by considering several basic phenomena related to plasma etching processes. First, it is known that in the absence of a glow discharge, the gases commonly used in plasma etching do not react with the surfaces to be etched. For example, CF_4 does not etch silicon without a discharge. This is due to the fact that CF_4 does not chemisorb on Si, and thus

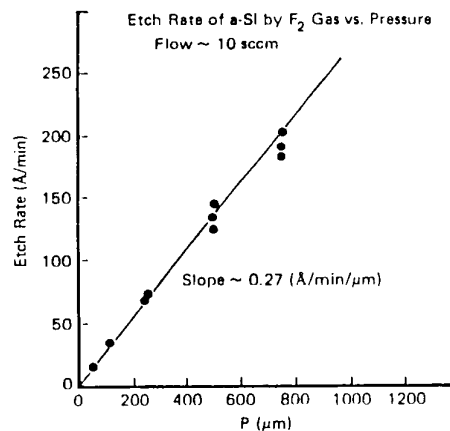


Fig. 6 The fluorine pressure dependence of the etch rate of amorphous silicon at room temperature¹². Reprinted with permission of the publisher, the Electrochemical Society.

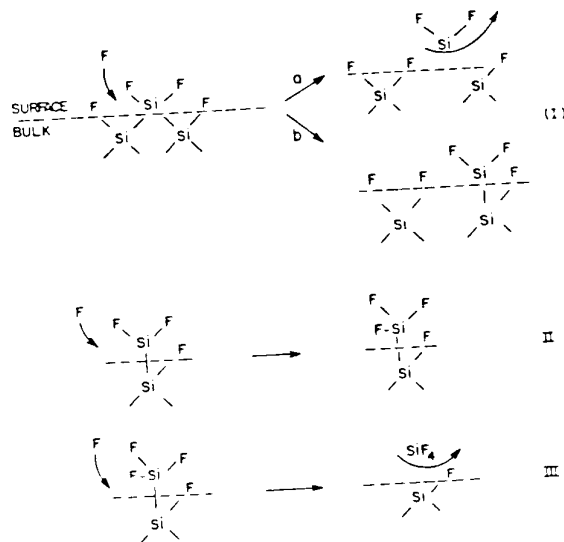


Fig. 7 Proposed mechanism for F-atom reaction with a silicon film leading to the products SiF₂ and SiF₄¹³. Reprinted with permission of the American Physical Society.

the step 3 of the dry-etching process described earlier does not occur. On the other hand, fluorine has been found to spontaneously etch Si, even without the presence of a discharge (Fig. 6)¹². Thus, when a discharge of CF₄ is created, it is not the CF₄ molecules themselves that participate in the etching reaction. Instead, the etching is accomplished by the radical species which are created by the dissociation of CF₄ molecules; namely fluorine atoms. The products of the Si-etching reaction are SiF₄ and SiF₂. A mechanism for the F-atom reaction with a Si film leading to gasification products has been proposed¹³, and is summarized in Fig. 7. The

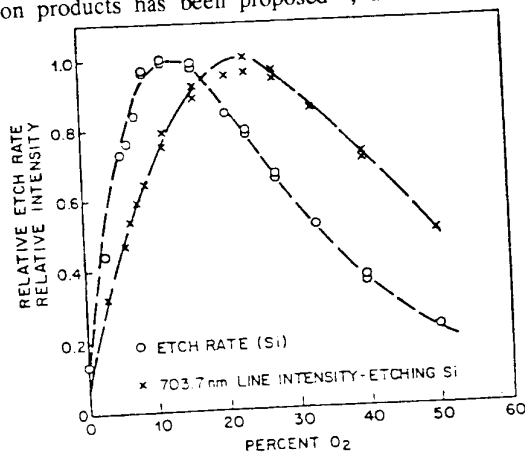


Fig. 8 The normalized etch rate for Si and the normalized intensity of the emission from electronically excited F atoms (703.7 nm line) versus the O₂ concentration in the CF₄-O₂ etch gas⁴. Reprinted with permission of the American Physical Society.

steady-state surface seems to be a stable "SiF₂-like" that must be penetrated by impinging F atoms in order for the SiF₄ to be formed. The etch rate of silicon (and SiO₂) in pure CF₄, however, is relatively low.

If small concentrations of O₂ are added to the CF₄ feed gas, however, the etch rates of both Si and SiO₂ are observed to dramatically increase (Fig. 8)¹⁴. The addition of the O₂ is also accompanied by an increase in the density of F-atoms in the discharge. Although several reasons have been advanced for this effect, it is certain that reactions between the oxygen atoms (or molecules) and the CF₄ molecules are responsible for the increased F-concentration. One of these reactions might be the gas phase oxidation of CF₃, to first form COF₂ + F, which then dissociates into CO + F₂. Another suggested reaction could involve CF₃ radicals that reach the silicon surface, and upon adsorption, contribute one C atom and 3 F-atoms to the surface. If an oxygen atom reacts with the adsorbed C atom, the 3 remaining F atoms are available to etch the Si. In any case, the etch rate of Si continues to increase until ~12% O₂ (by volume) is added. The etch rate of SiO₂ reaches its maximum value when ~20% O₂ is added. At greater concentrations, the additional O₂ dilutes the F concentration, and causes the etch rate to decrease. Figure 8 also shows that Si is etched much more rapidly than SiO₂ in CF₄-O₂ plasmas, and thus high selectivity of Si over SiO₂ is in such plasmas is easy to obtain.

If H₂ is added to the CF₄ feed gas, the etch rate of silicon decreases monotonically to almost zero for H₂ additions ≥ 40%. The etch rate of SiO₂, however, remains nearly constant for H₂ additions of up to 40% (Fig. 9)¹⁵. The silicon etch rate decrease occurs because the molecular hydrogen reacts with fluorine to form HF, and this drastically reduces the F atom concentration in the plasma. (It is said that the hydrogen *scavenges* F atoms). Although the effect of the Si etch rate decrease by itself may not be useful, the fact that the SiO₂ etch rate does not substantially decrease at the same time is valuable, because the *SiO₂-to-Si etch rate ratio* increases. As a result, this allows a higher *selectivity* with respect to the substrate to be achieved when etching SiO₂ over Si. This selectivity is necessary when SiO₂ films must be etched down to an underlying Si layer, without significantly etching the Si.

The mechanism responsible for the high SiO₂-to-Si etch rate selectivity involves the

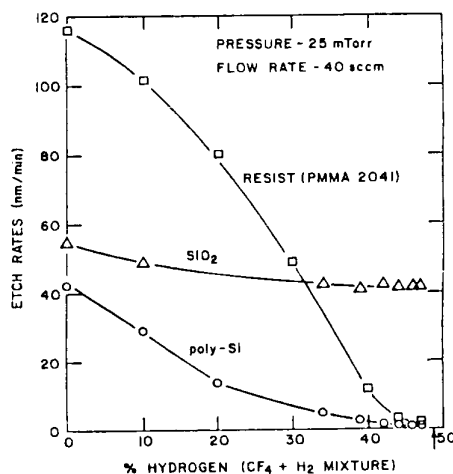


Fig. 9 The etch rate of Si, resist, and SiO₂ (measured in a reactive ion etching configuration) as a function of the concentrations of H₂ in the CF₄-H₂ etch gas¹⁵. Reprinted with permission of the publisher, the Electrochemical Society.

combination of two phenomena: 1) the deposition of a nonvolatile residue; and b) the role of oxygen in the etching of SiO_2 . If a nonvolatile layer (e.g. carbon residue) deposits on a surface during etching, and it is not removed, etching will cease. While such carbon residues are found to deposit on all surfaces inside an etch chamber containing $\text{CF}_4\text{-H}_2$ plasmas, less accumulation is observed to occur on oxide surfaces than on non-oxide surfaces. There are several ways in which carbon can be deposited on a surface in fluorocarbon discharges. One way involves the dissociation of CF_3 , or other fluorocarbon radicals, upon being chemisorbed on a surface. Less residue accumulates on SiO_2 surfaces because some of the carbon combines with the oxygen in the SiO_2 to form CO and CO_2 , which are volatile. This in turn allows the SiO_2 layer to continue to be etched under conditions when etching of the Si has ceased. Nevertheless, if the deposition rate of the carbon residue becomes too great, etching eventually stops on *all* surfaces in the chamber, including SiO_2 surfaces. Other gases which also consume F atoms have been found to produce high SiO_2 -to-Si selectivities¹⁶ (even without the use of H_2), including CHF_3 , C_3F_8 , and C_2F_6 . The reason for this effect is described as a part of the discussion on the *F/C ratio model*.

In practice, the exact process conditions that produce selective etching of SiO_2 over Si are generally empirically derived for each reactor. This is due to the fact that high selectivity requires that the process be operated very close to the demarcation between etching and polymerization (where etching abruptly ceases). Although the adjustment of plasma conditions to achieve high SiO_2 /Si selectivity remains an art, high selectivity is achievable. For example, selectivities of >20:1 at oxide etch rates of 600-1000 Å / min have been reported¹⁷.

Fluorine-to-Carbon Ratio Model

The *fluorine-to-carbon ratio (F/C) model*¹⁰ is one of the two models which have been evolved to assist in assimilating the large amount of information on chemical and physical mechanisms observed in plasma etching. That is, the model represents an attempt to organize such information into a framework that allows processes to be developed more efficiently, by providing some basis for predicting the effects of various parametric variations. The F/C ratio is the ratio of the fluorine-to-carbon species, which are the two "active species" involved in the etching of Si and SiO_2 (as well as other materials etchable in fluorocarbon plasmas, including Si_3N_4 , Ti, and W). The F/C ratio model does not attempt to account for the specific chemistry taking place in the glow discharge, but instead treats the plasma as a ratio of F to C species which can interact with the Si or SiO_2 surface. The generation or elimination of these "active species" by various mechanisms or gas additions then alters the initial F/C ratio of the inlet gas. Increasing the F/C ratio increases Si etch rates, and decreasing the F/C ratio lowers them.

For example, a pure CF_4 feed gas has an F/C ratio equal to four. If the plasma environment causes Si etching, however, this phenomenon consumes F atoms without consuming any carbon, and thus the F/C ratio is reduced. If more Si surface is added to the etching environment, the F/C ratio is further decreased, and the etch rate is also reduced. The addition of H_2 to the CF_4 feed gas causes the formation of HF, but does not consume any carbon, thereby the F/C ratio and the etch rate are again reduced. Finally, the utilization of gases in which the F/C ratio is <4, such as CHF_3 or C_3F_8 , also has the effect of producing an F/C ratio smaller than that present in a plasma of pure CF_4 . Their use is found to produce very similar effects in the etching chemistry as the other two procedures. Plasmas in which the F/C ratio is decreased to less than 4, are termed *fluorine-deficient plasmas*.

Conversely, the addition of O_2 has the effect of *increasing* the F/C ratio, because the oxygen consumes more carbon (by forming CO or CO_2), than F atoms (by the formation of COF_2). Other feed gases that can be added to increase the F/C ratio include CO_2 , F_2 , and NO_2 .

The cause of the high selectivity of SiO_2 -to-Si in $\text{CF}_4 + \text{H}_2$ plasmas can be elucidated

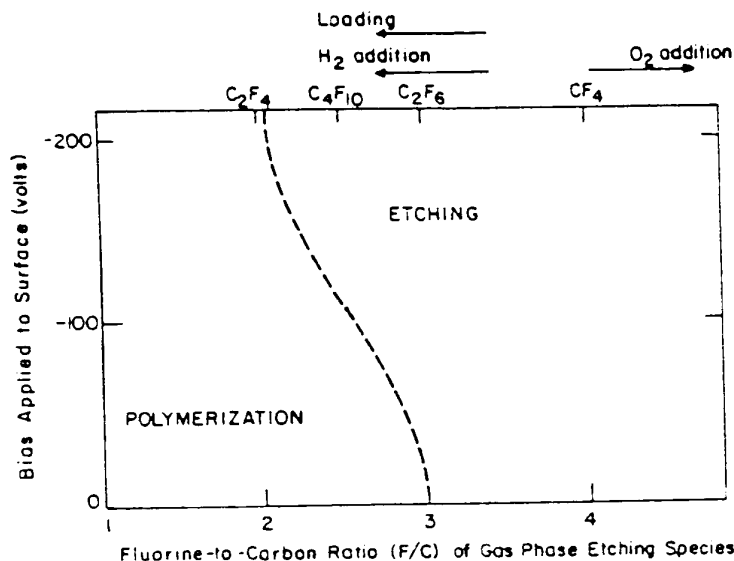


Fig. 10 Illustrative plot of the boundary between polymerizing and etching conditions as influenced by the fluorine-to-carbon ratio of the chemically reactive species and the bias applied to a surface in the discharge¹⁰. Reprinted with permission of the American Physical Society.

with the aid of the F/C ratio model. That is, even though the F/C ratio in such plasmas is less than 4, the SiO_2 contributes oxygen (which consumes carbon), thus locally compensating for the decreased F/C ratio at the SiO_2 surface¹⁹. As long as the F/C ratio at the oxide surface has a value close to that which exists in a pure CF_4 plasma, SiO_2 etching continues to proceed at the same rate. Meanwhile, since the F/C ratio at the Si surface is less than 4, the local etch rate decreases. To summarize, the F/C ratio model is useful for linking together the effects of a diverse set of phenomena, including the effects of many feed gases and SiO_2/Si selectivity.

The F/C ratio can also be used to qualitatively portray the demarcation between etching and polymerization as it varies according to changes in some process condition (Fig. 10). In this figure the boundary between polymerization (x-axis) is shown to vary as a bias voltage (y-axis) is applied to the substrate. The bias voltage has the effect of causing increased bombardment of the surface by energetic ions, which removes the nonvolatile residue layer by sputtering. This allows etching to occur at lower F/C ratios than if the carbonaceous polymer film were not simultaneously removed by sputtering and etching. This effect, as will be described in the following section, may be utilized as a technique to control sidewall profiles of etched layers.

ANISOTROPIC ETCHING and CONTROL OF EDGE PROFILE

Up to this point in our discussion we have considered the etching of Si and SiO_2 in fluorocarbon plasmas largely as a mechanism that proceeds by chemical action (i.e. the reaction of Si by F-atoms generated by the plasma to form SiF_4). If etching action is purely chemical, however, the removal of material is isotropic, and no advantage in dimensional control is gained over wet etching (Chap. 15). In such processes, the plasma plays no role other than to produce